CLAIMS

What is claimed is:

1. A sorbent particle comprising:

a vermiculite having a plurality of ion-exchange sites;

a plurality of polyvalent metal ions exchanged at some of said ion-exchange sites; and

a product of a plurality of thiocarbonate ions having chemically reacted with at least some of said polyvalent metal ions;

wherein said sorbent particle has a largest dimension of less than about twenty micrometers and said sorbent particle is operative to capture at least ninety percent of the ionic and elemental mercury present in a flue gas containing acid gases to which it is exposed.

2. A sorbent particle comprising:

a montmorillonite having a plurality of ion-exchange sites;

a plurality of polyvalent metal ions exchanged at some of said ion-exchange sites; and

a product of a plurality of thiocarbonate ions having chemically reacted with at least some of said polyvalent metal ions;

wherein said sorbent particle has a largest dimension of less than about twenty micrometers and said sorbent particle is operative to capture at least some of the ionic and elemental mercury present in a flue gas containing acid gases to which it is exposed.

3. A sorbent particle comprising:

a cryptocrystalline phyllosilicate having a plurality of ion-exchange sites;

a plurality of polyvalent metal ions exchanged at some of said ion-exchange sites; and

a product of a plurality of thiocarbonate ions having chemically reacted with at least some of said polyvalent metal ions;

wherein said sorbent particle is operative to capture at least some of the ionic and elemental mercury present in flue gas to which it is exposed.

4. A sorbent comprising:

a phyllosilicate having a plurality of ion-exchange sites;

a plurality of polyvalent metal ions exchanged at some of said ion-exchange sites; and

a product of a plurality of thiocarbonate ions having chemically reacted with at least some of said polyvalent metal ions;

wherein said sorbent operative to accomplish sustained removal of the ionic and elemental mercury present in an acidic flue gas to which it is exposed.

5. A sorbent comprising:

a non-zeolitic, amorphous aluminosilicate having a plurality of ion-exchange sites;

a plurality of polyvalent metal ions exchanged at some of said ion-exchange sites; and

a product of a plurality of thiocarbonate ions having chemically reacted with at least some of said polyvalent metal ions;

wherein said sorbent is essentially devoid of copper and polysulfides.

6. A composition of matter consisting essentially of:

a hydrated laminar magnesium aluminum ironsilicate having a plurality of ion-exchange sites;

a polyvalent metal ion derived from a highly acidic solution exchanged at some of said ion-exchange sites; and

a plurality of thiocarbonate ions chemically reacted with some of said polyvalent metal ions.

7. A composition of matter made by combining:

phyllosilicate substrate material having a plurality of ion-exchange sites at which cations are exchangeable;

a plurality of polyvalent metal ions derived from a highly acidic solution that are exchanged at some of said ion-exchange sites; and

a plurality of thiocarbonate ions which are chemically reactable with some of said polyvalent metal ions.

8. A composition made by combining effective amounts of:

means for supporting having a first layered structure and a plurality of ion-exchange sites at which cations are exchangeable;

a plurality of polyvalent metal ions which are reversibly substituted at some of said ion-exchange sites; and

a plurality of thiocarbonate ions which are chemically reacted to some of said polyvalent metal ions to produce a second layered structure having an inter-layer spacing of about five nanometers;

wherein said composition is capable of removing mercury from a gas stream containing trace amounts of acid gases.

9. A composition made by combining effective amounts of:

a montmorillinite having a plurality of ion-exchange sites at which cations are exchangeable;

a plurality of polyvalent metal ions in a highly acidic solution which are reversibly substituted at some of said ion-exchange sites; and

a plurality of thiocarbonate ions which are chemically reacted to some of said polyvalent metal ions;

wherein said composition is capable of sorbing mercury from a gas.

10. A process for the preparation of sorbent particles for ionic and elemental mercury comprising:

(a) reducing the size of a phyllosilicate support material having cation sites, the material being selected from the class consisting of vermiculites and montmorillonites, to a particle having a largest dimension of less than about twenty micrometers;

(b) providing the particle of step (a) with at least one cation capable of forming an insoluble sulfide and selected from the group consisting of antimony arsenic, bismuth, cadmium, cobalt, gold, indium, iron, lead, manganese, molybdenum, mercury, nickel, platinum, silver, tin, tungsten, titanium, vanadium, zinc, zirconium and mixtures thereof; and

(c) contacting the cation-containing particle of step (b) with a solution containing a thiocarbonate to produce a sorbent particle that is operative to capture at least some of the ionic

and elemental mercury present in flue gas containing trace amounts of acid gas species to which it is exposed.

11. A process for the preparation of adsorbent compositions for elemental mercury comprising:

providing a support material selected from the class consisting of phyllosilicates with at least one cation capable of forming an insoluble sulfide and selected from the group consisting of antimony arsenic, bismuth, cadmium, cobalt, gold, indium, iron, lead, manganese, molybdenum, mercury, nickel, platinum, silver, tin, tungsten, titanium, vanadium, zinc, zirconium and mixtures thereof; and

contacting the cation-containing support material of the foregoing step with a thiocarbonate.

12. A process for producing a sorbent particle comprising:

reducing the size of a phyllosilicate material to produce a phyllosilicate particle having a largest dimension of less than about twenty micrometers;

contacting the phyllosilicate particle with a highly acidic solution containing a plurality of polyvalent metal ions other than copper ions to produce an exchanged phyllosilicate particle;

separating the exchanged phyllosilicate particle from the solution;

contacting the exchanged phyllosilicate particle with a fluid containing a plurality of thiocarbonate ions to produce an amended phyllosilicate particle; and

separating the amended phyllosilicate particle from the fluid to produce a sorbent particle that is operative to capture at least some of the ionic and elemental mercury present in flue gas to which it is exposed.

13. A process for producing a sorbent particle comprising:

reducing the size of a vermiculite material to produce a vermiculite particle having a first layered structure and a largest dimension of less than about twenty micrometers;

contacting the vermiculite particle with a solution containing a plurality of polyvalent metal ions to produce an exchanged vermiculite particle;

separating the exchanged vermiculite particle from the solution;

contacting the exchanged vermiculite particle with a fluid containing a plurality of thiocarbonate ions to produce an amended vermiculite particle containing an amendment having a second layered structure; and

separating the amended vermiculite particle from the fluid to produce a sorbent particle that is operative to capture at least some of the ionic and elemental mercury present in flue gas to which it is exposed.

14. A process for producing a sorbent particle comprising:

reducing the size of a montmorillonite material to produce a montmorillonite particle having a largest dimension of less than about twenty micrometers;

contacting the montmorillonite particle with a solution containing a plurality of polyvalent metal ions to produce an exchanged montmorillonite particle;

separating the exchanged montmorillonite particle from the solution;

contacting the exchanged montmorillonite particle with a fluid containing a plurality of thiocarbonate ions to produce an amended montmorillonite particle; and

separating the amended montmorillonite particle from the fluid to produce a sorbent particle that is operative to capture at least some of the ionic and elemental mercury present in flue gas to which it is exposed.

15. A process for producing a sorbent comprising:

contacting a phyllosilicate substrate material with a solution containing a polyvalent metal ion to produce an exchanged phyllosilicate;

separating the exchanged phyllosilicate from the solution;

contacting the exchanged phyllosilicate with a fluid containing a thiocarbonate ion to produce an amended phyllosilicate;

separating the amended phyllosilicate from the fluid to produce a sorbent.

16. The process of claim 15 further comprising:

washing the exchanged phyllosilicate after it is separated from the solution.

17. The process of claim 15 further comprising:

washing the amended phyllosilicate after it is separated from the fluid.

18. The process of claim 17 further comprising:

drying the amended phyllosilicate after it is washed.

19. The process of claim 15 further comprising:

processing the solution separated from the exchanged phyllosilicate using a technique selected from the group consisting of

reusing the solution, and

treating the solution to recover unused metal ions.

20. The process of claim 15 wherein the pyllosilicate substrate material is contacted with a solution containing a polyvalent metal ion selected from the group consisting of

a bivalent tin ion,

a tetravalent tin ion,

a bivalent iron ion,

a trivalent iron ion,

a titanium ion,

a manganese ion,

a zirconium ion,

a vanadium ion,

a zinc ion,

a nickel ion,

a bismuth ion,

a cobalt ion,

and a molybdenum ion.

21. The process of claim 15 wherein the exchanged phyllosilicate is separated from solution using settling, filtration or centrifuging.

22. The process of claim 15 wherein the phyllosilicate substitute material is contacted with the solution using a method selected from the group consisting of

batch contacting,

co-current contacting, and

counter-current contacting.

23. The process of claim 15 wherein the exchanged phyllosilicate is contacted with an aqueous solution comprising sodium thiocarbonate and/or potassium thiocarbonate.

24. The process of claim 15 wherein the exchanged phyllosilicate is contacted with a solution containing a mixture that comprises sodium thiocarbonate and/or potassium thiocarbonate.

25. The process of claim 15 wherein the fluid is an aqueous solution and the process further comprises:

adjusting the pH of the aqueous solution to a pH of in the range of about 7 to about 8.

26. A sorbent production system comprising:

means for contacting a silicate substrate material with a solution containing a polyvalent metal ion other than a copper ion to produce an exchanged silicate;

means for separating the exchanged silicate from the solution;

means for contacting the exchanged silicate with a fluid containing a thiocarbonate ion to produce an amended silicate; and

means for separating the amended silicate from the fluid to produce a sorbent.

27. A method for removing mercury from a gas stream containing an acid gas, the method comprising:

injecting and entraining the sorbent particle of claim 2 into the gas stream containing ionic and elemental mercury under conditions wherein at least a portion of said elemental and ionic mercury sorbs onto the sorbent particle during its exposure to the gas stream; and

removing the sorbent particle from the gas stream.

28. The process of claim 27 wherein the removing step is accomplished by means of a process selected from the group consisting of

filtration,

electrostatic precipitation,

an inertial method, and

wet scrubbing.

29. A method for removing mercury from a gas stream, the method comprising:

injecting and entraining the sorbent particle of claim 3 into the gas stream containing ionic and elemental mercury under conditions wherein at least a portion of said elemental and ionic mercury sorbs onto the sorbent particle during its exposure to the gas stream; and

removing the sorbent particle from the gas stream by means of a process selected from the group consisting of

filtration,

electrostatic precipitation,

an inertial method, and

wet scrubbing

wherein the injecting and entraining step involves injecting and entraining the sorbent particle into a flue gas stream containing a plurality acid gases including sulfur dioxide in the range of a few hundred to a few thousand ppm, hydrogen chloride up to 20 ppm, and nitrogen oxides in the range of 200 to 2,000 ppm.

30. A process for removing mercury from a gas, the process comprising:

contacting the gas containing mercury with a sorbent produced using the process of claim 15.

31. A technique for removing mercury from a gas, the technique comprising:

contacting the composition of matter of claim 6 with a gas stream containing mercury at a temperature that does not exceed 350 degrees Fahrenheit for at least one second to produce a mercury-laden adsorbent composition comprising adsorbed mercury;

removing the mercury-laden adsorbent composition from the gas stream; and

heating the mercury-laden adsorbent composition to a temperature of about 500 degrees Fahrenheit to desorb the adsorbed mercury from the mercury-laden adsorbent composition and produce a regenerated adsorbent composition t; and

removing the adsorbed mercury from the vicinity of the regenerated adsorbent composition.

32. A method for removing mercury from a gas, the method comprising:

flowing the gas containing mercury through a fixed or fluidized bed comprised of the composition of claim 8.

33. A method for removing mercury from a gas, the method comprising:

injecting and entraining the composition of matter of claim 6 into a gas stream containing mercury at an operating pressure within about plus or minus 0.5 to 1.0 psig of ambient conditions; and

removing the composition of matter from the gas stream to produce a collected composition of matter that remains exposed to the gas stream and that is capable of sorption of mercury, said removing be accomplished by a process selected from a group of methods consisting of:

filtration,

electrostatic precipitation,

inertial methods, and

wet scrubbing;

wherein at least a portion of said sorption of mercury occurs onto the collected composition of matter while it remains exposed to the gas stream.

34. A system for removing mercury from a gas, the system comprising:

means for flowing the gas containing mercury through a sorbent container having a bed comprising the composition of matter described in claim 7 operating at gas temperatures greater than 500 degrees Fahrenheit and pressures greater than ambient conditions; and

means for removing the mercury from the composition by reducing the operating pressure of the sorbent container, while maintaining the temperature of the composition at or near the normal operating temperature for the process.

35. A system for removing mercury from a gas, the system comprising:

an injector for injecting the sorbent particle of claim 1 into a flue gas stream;

a contactor for contacting the sorbent with the flue gas stream and producing a mercury-laden sorbent; and

a separator for separating the mercury-laden sorbent from the flue gas stream.

36. The system of claim 35 further comprising:

a regenerator for regenerating the mercury-laden sorbent.

37. A system for removing mercury from a flue gas, the system comprising:

a source of flue gas that contains an acid gas;

means for exposing the flue gas to the sorbent particle of claim 2.

38. The system of claim 37 wherein the means for exposing comprises an injection and entrainment system and the system further comprises:

means for separating the sorbent from the flue gas after the sorbent has contacted the flue gas for a time that is effective for the sorbent to capture mercury present in the flue gas.

39. A system for removing mercury from a gas, the system comprising:

means for injecting the sorbent particle of claim 1 into a flue gas stream;

means for contacting the sorbent with the flue gas stream and producing a mercury-laden sorbent; and

means for separating the mercury-laden sorbent from the flue gas stream.

40. A method for removing mercury from a gas, the method comprising:

a step for injecting the sorbent particle of claim 3 into a flue gas stream;

a step for contacting the sorbent with the flue gas stream and producing a mercury-laden sorbent; and

a step for separating the mercury-laden sorbent from the flue gas stream.

41. A power plant comprising the system of claim 36.

42. A power plant comprising a mercury removal system operated in accordance with the method of claim 40.

43. A power grid comprising the power plant of claim 41.

44. An incinerator comprising the system of claim 39.

45. An incinerator plant comprising a mercury removal system operated in accordance with the technique of claim 33.

46. A concrete additive comprising:

a fly ash containing the adsorbent composition of claim 5 that has been used to remove mercury from a gas stream and is mercury laden.

47. A method for making a concrete additive that comprises:

adding to a cement and aggregate mixture a fly ash containing a sorbent that has been used to remove mercury from a gas stream in the power plant of claim 41.

48. A concrete made by combining:

a cement;

an aggregate; and

a fly ash containing the composition of claim 7 that has been used to remove mercury from a gas stream.

49. A composition made by combining effective amounts of:

a synthetic montmorillinite having a plurality of ion-exchange sites at which cations are exchangeable;

a plurality of polyvalent metal ions in a highly acidic solution which are reversibly substituted at some of said ion-exchange sites; and

a plurality of sulfide ions which are chemically reacted to some of said polyvalent metal ions;

wherein said composition is essentially devoid of polysulfide ions and is capable of sorbing mercury from a gas.

50. A sorbent particle comprising:

a cryptocrystalline phyllosilicate having a plurality of ion-exchange sites;

a plurality of polyvalent metal ions exchanged at some of said ion-exchange sites; and

a plurality of inorganic polysulfide ions chemically reacted to at least some of said polyvalent metal ions;

wherein said sorbent particle is essentially devoid of polysulfides said sorbent particle is operative to capture at least some of the ionic and elemental mercury present in flue gas to which it is exposed.

51. A sorbent comprising:

a non-zeolitic, amorphous aluminosilicate having a plurality of ion-exchange sites;

a plurality of polyvalent metal ions exchanged at some of said ion-exchange sites; and

a plurality of inooganic polysulfide ions chemically reacted to at least some of said polyvalent metal ions;

wherein said sorbent is essentially devoid of copper and polysulfides.

52. A composition made by combining effective amounts of:

means for supporting having a first layered structure and a plurality of ion-exchange sites at which cations are exchangeable;

a plurality of polyvalent metal ions which are reversibly substituted at some of said ion-exchange sites; and

a plurality of polysulfide ions which are chemically reacted to some of said polyvalent metal ions to produce a second layered structure having an inter-layer spacing of about five nanometers;

wherein said composition comprises essentially no polysulfides and is capable of removing mercury from a gas stream containing trace amounts of acid gases.

53. A composition made by combining effective amounts of:

a montmorillinite having a plurality of ion-exchange sites at which cations are exchangeable;

a plurality of polyvalent metal ions that are other than copper ions in a highly acidic solution which are reversibly substituted at some of said ion-exchange sites; and

a plurality of polysulfide ions or thiocarbonate ions which are chemically reacted to some of said polyvalent metal ions;

wherein said composition is essentially devoid of polysulfides and is capable of sorbing mercury from a gas.

54. A sorbent particle comprising:

a cryptocrystalline phyllosilicate having a plurality of ion-exchange sites;

a plurality of polyvalent metal ions exchanged at some of said ion-exchange sites; and

a plurality of polysulfide ions or thiocarbonate ions chemically reacted to at least some of said polyvalent metal ions;

wherein said sorbent particle is operative to capture at least some of the ionic and elemental mercury present in flue gas to which it is exposed.

55. A sorbent comprising:

a non-zeolitic, amorphous aluminosilicate having a plurality of ion-exchange sites;

a plurality of polyvalent metal ions exchanged at some of said ion-exchange sites; and

a plurality of polysulfide ions or thiocarbonate ions chemically reacted to at least some of said polyvalent metal ions.

56. A composition made by combining effective amounts of:

means for supporting having a first layered structure and a plurality of ion-exchange sites at which cations are exchangeable;

a plurality of polyvalent metal ions which are reversibly substituted at some of said ion-exchange sites; and

a plurality of sulfide ions, polysulfide ions or thiocarbonate ions which are chemically reacted to some of said polyvalent metal ions to produce a second layered structure;

whereby said composition is capable of removing mercury from a gas stream containing trace amounts of acid gases.

57. A method for removing mercury from a gas, the method comprising:

flowing the gas containing mercury through a fixed or fluidized bed comprised of the composition of claim 56.

58. A system for removing mercury from a gas, the system comprising:

an injector for injecting the composition of claim 56 into a flue gas stream;

a contactor for contacting the composition with the flue gas stream and producing a mercury-laden composition; and

a separator for separating the mercury-laden composition from the flue gas stream.

59. The system of claim 58 further comprising:

a regenerator for regenerating the mercury-laden composition.

60. A concrete additive comprising:

a fly ash containing the composition of claim 56 that has been used to remove mercury from a gas stream and is mercury laden.